Yesterday and Today in Refrigeration

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The Temperature Research Foundation of Nash-Kelvinator Corporation is a public service institution which functions as a clearing house for authoritative information on all aspects of modern temperature engineering as it relates to the preparation and preservation of food, to domestic and industrial heating and air conditioning.

It was founded by the Kelvinator Division of Nash-Kelvinator Corporation, pioneer manufacturer of domestic electric refrigerators and allied temperature control products, to make available to the American people the latest scientific and practical data on temperature control. As a great American industrial organization, Nash-Kelvinator Corporation believes that its private interest can best be served through such enlightened devotion to the public interest.

Through a broad educational program, Nash-Kelvinator's Foundation is endeavoring to stimulate public appreciation of the vital importance of temperature control to the health, comfort, convenience and leisure of millions of American families, thereby lending new meaning to Lord Kelvin's dictum "I've thought of a better way." It publishes and distributes, free of charge, authoritative brochures and makes available to the radio and the press authentic data on temperature engineering. The enthusiastic reception accorded The Temperature Research Foundation by group leaders throughout the country during the first six months of its existence provides evidence that this organization is filling a widespread and long-felt public need in supplying authentic data on these subjects.

Correspondence is invited with groups, organizations and individuals who are concerned with the various phases of modern temperature engineering, or who are seeking practical aid on the solution of specific temperature control problems.

Yesterday and Today in Refrigeration

The modern electric refrigerator stands today as the culmination of a long and colorful series of scientific developments. Famous men—Nicolas Carnot, the nineteenth century French physicist; Antoine Lavoisier, founder of modern chemistry; James Prescott Joule, first scientist to discover the mechanical equivalent of heat; William Thomson, Lord Kelvin, coordinator of the theories of thermodynamics; Robert Boyle, the British natural philosopher and chemist; Francis Bacon, England's illustrious jurist, philosopher and scientist; Louis Pasteur, who proved the theory of bacterial growth in its relation to disease; Antony van Leeuwenhoek, the Dutch scientist who was first to see bacteria and protozoa by use of the microscope; Hermann Helmholtz, Germany's great nineteenth century physicist; Michael Faraday, the English scientist of the last century, and others furnished the ground work for this outstanding engineering feat of today. Because of those early pioneering efforts Cullen found it possible to invent the vacuum machine, Edmund Carré the absorption machine, Dr. John Gorrie the cold air machine, and Jacob Perkins the compression machine. Later John C. De La Vergne, Fred W. Wolf and Dr. Karl Von Linde, all scientists of modern times, improved their devices and developed them to a point of practical efficiency.

Cooling by Evaporation

From earliest times people have known and employed the principle of evaporation to lower the temperature of a substance below that of its immediate surroundings. Centuries ago in Egypt and in India, the effects of cooling were obtained by placing shallow porous vessels with palm leaves, so that water seeping through the sides of the vessel might evaporate and cool the contents of the jar. In some of the drier climates the claim was made that a thin crust of ice could be formed in the vessels by these crude methods of evaporation. There the cooling was usually performed at night, taking advantage of lower surrounding

temperatures as well as evaporation. Frescoes as early as 2500 B.C. show Egyptian slaves fanning jars, probably containing wine and water. No doubt these jars were porous and allowed moisture to seep to the outside, thus supplying the evaporating fluid which would cool the rest of the contents. The cat wetting her fur in hot weather is applying by instinct this same principle of evaporation in producing "cold comfort."

Cooling by Ice and Snow

Nero, in supplying added luxuries for his exotic feasts, had literally hundreds of his slaves carrying ice and snow from the mountains to the banquet halls in insulated containers on their backs. This ice and snow was used to cool his wines, fruit and water. The Roman method of storage for ice was indeed a far cry from our present standards of cleanliness in electric refrigeration. After covering the ice and snow with grasses and sod in specially excavated caves and ditches, further insulation was provided by piling on top a thick layer of dung, obtained from the nearest sheep pen. Since the ice thus stored was put directly into the wines, it is not strange that numerous references are made in Roman literature to frequent straining of their beverages.

People have known for a long time that wine to taste right needs to be properly tempered. Old connoisseurs of the renowned wines of Spain and Portugal would never have thought of tasting any wine which had not been appropriately cooled. In a few parts of the world, especially in Sicily, it was discovered that Dame Nature herself had thoughtfully provided cooling chambers. Hillside caves were found with natural temperatures often as low as 50 degrees to 60 degrees F. In these caves wines, milk and other foods were stored, and more troublesome methods of refrigeration dispensed with. As these natural caves were few and seldom conveniently located, people before long had acquired the habit of digging holes for this purpose near their homes, especially where springs with cold flowing streams could be used for additional cooling. In later years it became the practice to pack these holes with ice, where no spring water was available, and place the wines and milk directly upon it. As time went on housewives discovered that ice placed anywhere in the excavation cooled the air sufficiently to cool

in turn whatever else was stored there. From this discovery sprang the food cellar of but a few decades ago. Now we have changed to a basement which often contains the heating plant and recreation room of the modern house, with the clean, sanitary refrigerator right in the kitchen, enabling the housewife to have controlled temperatures, conveniently located.

The use of natural ice for domestic refrigeration grew rapidly. In France, however, beginning in the early part of the sixteenth century, financial practices of the government came close to revolutionizing refrigeration methods. Seeking financial gain, the French government converted the ice sheds and fields into a strict state monopoly. The price of ice rose to such extremes as to make its cost practically prohibitive. It is an historical fact that little or no ice at all was sold to the public, until the government allowed the industry to return to private control, when it again enjoyed natural expansion.

Cooling by Refrigerants

The government ice monopoly in France provided further justification for the old adage that necessity is the mother of invention. During the time that ice was too costly to use, men set themselves to the task of finding a less expensive method of cooling their wines. Blasius Villafranca, a Spanish physician, is given credit for discovering the use of saltpeter as a refrigerant, and in 1550 this was employed almost exclusively. The method involved was to immerse a bottle of wine in the coldest water obtainable, adding saltpeter to the water gradually until its temperature was lowered to the desired level. During the cooling process the bottles were kept in motion, helping to transfer the heat from the bottle to the saltpeter bath. By 1630 a flourishing trade in beverages cooled in this manner was being carried on in the streets by limonadiers.

Experiments conducted by Toselli showed that ammonium nitrate used in water would reduce its temperature down to 40 degrees F. He proved that thin shells of ice could be formed in molds containing water and immersed in this brine. Large cakes of ice were made by freezing numbers of these thin shells together.

Sir Francis Bacon was one of the early experimenters with cold as a food preservative. Because of his desire to discover whether snow would "keep foods," he stopped to pack a fowl during a journey. The chill he contracted in thus appeasing his scientific curiosity precipitated a fatal attack of bronchitis, but it is claimed that he wrote cheerfully from his deathbed that "the experiment . . . succeeded exceedingly well."

Robert Boyle in the seventeenth century undertook the study of cold, and wrote an "*Experimental History of Cold*," containing besides all that was known about cold up to that time, the results of many experiments he himself conducted to prove the truth or falsity of previous theories. Boyle's work was the first scientific experimentation of any kind to bring together and test all of the known facts in a particular field of investigation.

By 1691 the secret of preserving foods by drying, salting or smoking had been used for centuries, but in that year for the first time, people became acquainted with the fact that frozen foods keep a long time without decomposition. "And if they kill any beast, they preserve the flesh without stink or putrefaction, without salt, hardened only with the freezing wind."[1]

Leeuwenhoek (1632-1723) while experimenting with microscopes discovered the presence of the tiny organisms which we know today as bacteria. But it was not until the middle of the nineteenth century that Louis Pasteur established a definite relationship between bacteria and disease. It was this important discovery that pointed the way to the solution of the problem of the causes of food putrefaction and spoilage. A simple bacteria form, the "schizomyceter," has been found to be the cause of food decomposition, and to be especially active at temperatures between 50 degrees and 80 degrees F. The result of this bacterial action in foods varies, from decreased palatability, bad flavors and odors, to effects on health ranging from indigestion to infectious disease. The old ailment known as "summer complaint" is now attributed to spoiled food, not sufficiently bad to be detected by smell, or by appearance, unless inspected under the microscope. To keep food safe for

[1] Works of Robert Boyle by T. Birch, 1744, Vol. II, p. 343.

consumption it must be preserved at temperatures below 50 degrees F., preferably below 45 degrees, and to keep its texture as found when fresh, it must be kept above 32 degrees F. If food is allowed to freeze, reactions take place which tend to destroy the cell structure and cause other chemical changes. The temperature range most satisfactory for preserving food, therefore, is between 32 degrees and 50 degrees F. Refrigeration is a necessity for preventing waste of food and decay, and ultimately serves as an effective health insurance policy for all.

The Beginning of Thermodynamics

The opening years of the nineteenth century witnessed a growing interest in the study of heat principles. Nicolas Carnot, who developed the theory upon which rests the heat engine, was born in 1796. James Prescott Joule, who was to prove that heat energy may be turned into mechanical energy or the process reversed, was born in 1818. Other contributors along similar lines during this period were Helmholtz, who in 1847 delivered his learned thesis on "The Conservation of Energy;" Rudolpf Clausius, the German physicist who advanced the true basis for the theory of heat flow; and Michael Faraday, who in 1823 successfully demonstrated that gaseous ammonia, carbon dioxide, and some other gases could be changed to liquids by compression and cooling of the compressed gases back to their original temperatures.

It remained for William Thomson, Lord Kelvin, about the middle of the nineteenth century to coordinate the different theories that had been brought forward concerning heat and energy. He adjusted the work of Carnot and put it in accord with the principles of Helmholtz and Joule. Not until then was Lord Kelvin successful in having the scientific world accept these theories of thermodynamics. Further experimentation and studied application of these early scientific accomplishments provided the starting point for the development of modern refrigeration.

Principles of Heat

Cold may be said to be the effect of the absence of heat, and best describes a physiological sensation. It is the sensation produced when

the human body comes in contact with another substance at a lower temperature. *Hot* describes the sensation produced when the substance touched has a higher temperature than that of the human body. Thus *hot* and *cold* are merely relative terms and are adjectives used to describe the sensations produced in the human body.

Heat, however, unlike the term *hot,* represents not a relation but a quantity of energy, changes in which may or may not produce a change in temperature. Let us illustrate the principle of heat with the three forms of water—ice, liquid and steam. When heat is applied from a gas burner to a quantity of ice at 32 degrees F., the heat from the gas flame passes through the containers and is absorbed by the ice, which remains at its constant temperature of 32 degrees while being changed from a solid to a liquid form. When the ice has been entirely melted into water, the addition of more heat raises the temperature of the water until it reaches 212 degrees F., at which point the water boils and is transformed into the gaseous state, steam. At the boiling point the application of more heat will not raise the temperature of the water, for the liquid is then escaping in the form of vapor.

If heat were to be subtracted from the steam by a cooling process, a liquid would again be formed. Continued cooling of the liquid, which is to say, constantly subtracting heat from it, would lower the temperature of the liquid to 32 degrees F., the freezing point where the water would slowly be changed back to ice at the same temperature of 32 degrees F. Thus, the addition to or subtraction of heat from a substance, is accompanied either by a change of temperature or a change of form. The process by which the solid is turned into a liquid is called melting and the heat supplied to bring about this change is known scientifically as the latent heat of fusion. Changing a liquid into a vapor is boiling, the heat required for this process being known as the latent heat of vaporization.

The reverse processes are called freezing and condensation; the heat changes involved are known as latent heats of fusion and vaporization in each case. In producing these changes in water the latent heat of vaporization is over five times the amount required to raise its temperature from freezing to boiling.

How "Cold" Is Manufactured

These are essentially the principles which operate in a modern mechanical refrigerator to provide the desired cooling. In the working of a mechanical refrigerator a liquid called the refrigerant is used, which will boil at a temperature low enough to freeze water. The latent heat of vaporization of the refrigerant, or the heat which causes the refrigerant to boil, comes from the contents of the refrigerator which are being cooled. In this manner large quantities of heat are extracted from the refrigerator interior at a constant temperature. The liquid refrigerant will continue to boil and absorb heat from the contents of the refrigerator until the temperature of the interior is cooled to that of practically constant temperature of the boiling refrigerant, which is 32 degrees F. More liquid refrigerant must be supplied to replace that which is boiled away as the cooling process goes on and on. In order that a new supply of the liquid need not be purchased at frequent intervals, the vapors of the boiling refrigerant are conserved. The refrigerator mechanism is designed to catch the vapor of the refrigerant as it rises, compress it, and then cool it back to a convenient temperature. In the case of the household electric refrigerator this convenient temperature is the temperature of the room where the refrigerator is located. The vapor is liquefied by allowing the heat it has absorbed from the refrigerator to be radiated into the cooling medium. Then the liquid is made to flow back into the boiling container where it begins to boil again, thus working in a never-ending cycle: first, absorption of heat from the refrigerator as it boils or vaporizes; next, compression of the vapor so that absorbed heat from the refrigerator can be radiated to the surrounding atmosphere, enabling the gas to condense into a liquid again. The liquid is then ready to be returned to the heat absorber in the cold compartment as it is needed to maintain an adequate supply.

Refrigerating Systems

There are four types of refrigerating systems: the vacuum machine, the cold air machine, the absorption machine, and the compression machine. The Kelvinator is an example of the compression machine.

Vacuum Machine

Cullen invented the vacuum machine in 1755, Wallace improved it in 1824, and Edmund Carré added still further improvements to it in 1850. Fleuss invented a hand operating model of the vacuum machine in 1870 for household use, and Franz Windhauser in 1881 installed a commercial type in the Aylesbury Dairy Company at Maywater, England. This English machine was capable of producing from 12 to 15 tons of ice each day. Similar machines were installed in New York, Baltimore and San Francisco, all of them proving to be failures. Even the English vacuum machine was removed shortly after its installation. There are to be found still in operation today in some hot countries, a few of these old hand-driven machines, capable of producing a pound or two of ice in a few minutes.

Cold Air Machine

The original cold air machine was built as a laboratory model by M. Hoell of Chemnitz, Germany, about 1755. The principle of Hoell's invention was elaborated by Dr. John Gorrie of Apalachicola, Florida, who developed it into a useable apparatus. He was granted a patent on his cold air machine in 1851. Gorrie had been inspired in his work by his great desire to relieve the suffering of humanity from malaria. When Florida was invited years later to place two statues in Washington, D. C., one of the two men so honored was John Gorrie.

Not many years afterward Nesmond built a similar machine, and in Scotland in 1861 Dr. Alexander Kirk developed a closed cycle machine which was installed at Bath Gate, near Edinburgh, and also at Hong Kong, China. Windhauser, utilizing a slightly improved design, succeeded in producing temperatures as low as 40 degrees below zero F.

These machines were even put into use on shipboard, and it is recorded that the ship Strathleven arrived in England in February, 1879, with 34 tons of mutton and beef aboard, cooled by an improved Windhauser machine, built by Bell-Coleman of Glasgow, Scotland. Nearly 144 horse-power-hours were required for each ton of refrigeration produced, which is far from equalling the efficiency of modern refrigeration machinery. The present figure is about 24 horse-power-hours

per ton. A ton of refrigeration is the amount of heat extracted in freezing one ton of water at 32 degrees F. into ice at the same temperature. Like the vacuum machine, the cold air machine become impractical as newer methods were developed, and soon passed into disuse.

Absorption Machine

Ferdinand P. E. Carré of Paris, a brother of Edmund Carré who had worked on the vacuum machine, was the first to apply the absorption principle to refrigeration, taking advantage of the affinity of water for ammonia. The absorption machine which he construed in 1860 consisted of two vessels, one containing pure ammonia, the other a mixture of water and ammonia. During the refrigeration cycle, the liquid ammonia is boiled off from the vessel containing its pure form, the ammonia vapor thus produced dissolving in the vessel containing the mixed water and ammonia. Then some form of heat such as steam is applied to this vessel and the ammonia content is driven off. The ammonia vapor is cooled with water to a liquid, and is ready to pass to the ammonia vessel to repeat the cycle.

Carré's absorption machine was soon found to require large quantities of both steam and water for cooling, but still proved to be more efficient than the cold air machine. The absorption type of refrigerating system may be found in use at the present time.

The principal difference between the absorption and the compression machines is in the method used to remove and handle the refrigerant vapors. In an absorption machine the vapor is removed by chemical or physical reactions, the compression machine uses mechanical methods to perform the same process. Both systems discharge the vapors at high pressure and temperature, to be condensed back into liquid form.

Compression Machine

In 1834 the compression type of refrigeration machine was patented by Jacob Perkins, an American engineer living in London. A number of other scientists soon commenced work on the same principle. Outstanding was the work of Shaw in 1836 and that of A. C. Twinning of New Haven, Connecticut, in 1855. Twinning's machine was capable of manufacturing 1600 pounds of ice in 24 hours, nearly a ton a day.

Thus by the year 1870, four types of refrigeration machines had been introduced, but until that time no one had attempted to apply to refrigeration systems the theory which had been formulated by Lord Kelvin after much coordination and correlation of lesser theories. Dr. Karl Von Linde, of Munich, Germany, undertook the task at last, endeavoring to establish three fundamentals: first, the relation between the heat abstracted and the energy expended in refrigeration; second, the methods of abstracting the heat; and third, the degree of efficiency of contemporary systems in relation to their theoretical capacity. Following his investigation he published an article entitled, "*Improved Ice and Refrigerating Machinery*," which provided a real scientific basis for further experimentation.

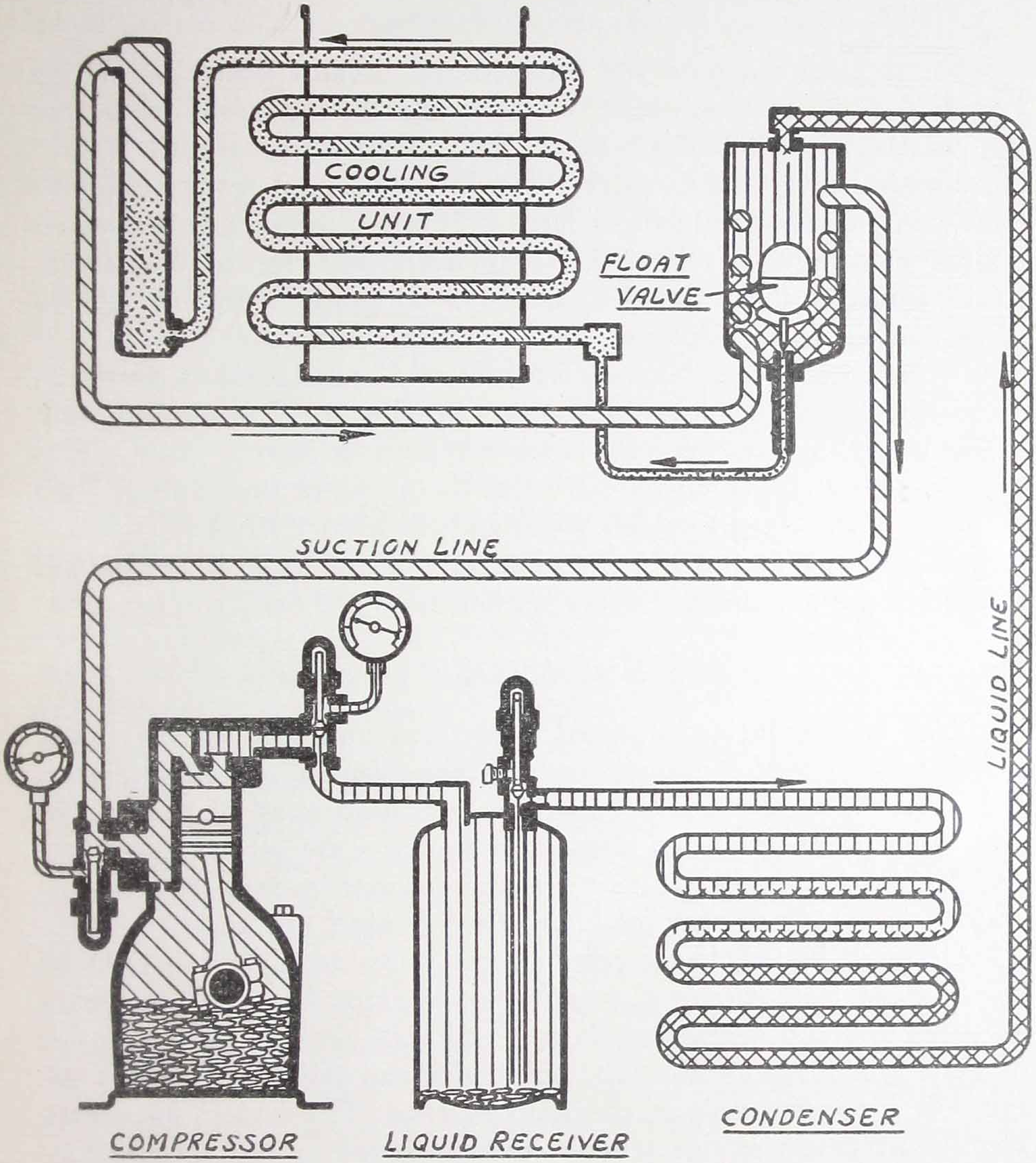
Operation of a Household Refrigerator

Just how is refrigeration accomplished in a modern domestic refrigerator and what are the elements used? The air-cooled compression machine, most common of household refrigerators, consists of six main parts: (1) the cooling unit or heat absorber, (2) the condenser or heat radiator, (3) the refrigerant or cooling medium contained within the closed system, (4) a compressor for collecting the refrigerant vapors as they come from the evaporator and discharging them so they may be condensed again into liquid refrigerant, (5) the liquid feed device, and (6) a thermostat (not shown) which controls the operation to make it automatic.

The evaporator holds the low temperature liquid refrigerant, and by absorbing the heat from the cabinet, turns some of the liquid into a vapor or gas which passes through the tube into the compressor, where it is compressed and moved into the condenser. Here the heat of the vapor is radiated to the atmosphere, allowing the gas thus cooled to condense into a liquid, which flows into a feeding device that returns the liquid to the evaporator where it started. The thermostat controls the operation of the compressor.

If there were a constant flow of heat into the evaporator, a machine could be designed that would remove and compress the refrigerant vapor at just the speed it evaporated; but such is not the case. Sometimes ice or desserts are being frozen, or again, some warm food may

be placed into the cabinet to cool, all of which change the quantity of heat that the boiling liquid must absorb. It would be wasteful to have the compressor going when it was not required to remove vapor, and equally as unsatisfactory not to remove the vapor as fast as it formed.



Refrigerant Cycle

The thermostat connected to the evaporator starts and stops the compressor as it becomes necessary to remove the accumulated vapor. Thus the cycle of the machine is one of absorbing heat at one temperature, and radiating it at another.

Later Developments

About 1870 the need for refrigeration became noticeable in the breweries, some of which were forced to suspend operations during the hot weather. The development of refrigeration now became closely allied with the brewing industry. After Dr. Linde's paper was published, he was invited by a number of large brewers to install a system of his design, incorporating the latest knowledge and improvements. He finally agreed to the proposal, and in 1883 the Linde Company installed its first refrigerating equipment at Wiesbaden, Germany.

In the United States Thomas Rankin and Daniel Holden were working on these new machines, and Rankin installed a refrigerating system in the New York brewery of Jacob Ruppert, as early as 1879. From then on the refrigeration industry lists the names of such men as John A. De La Vargne and Fred W. Wolf, and the history is one of technical refinements and manufacturing changes along with their application to more and more different types of conditions and uses.

Modern Household Refrigeration

"The real invention consisted in the slow and accumulative work which came out of the quiet study of the scientist, the experimental laboratory of the investigator, and the profound mind of the thinker who was able to establish a connection between the various discoveries extending over a period of centuries and forge them into the unbreakable chain of our present methods of mechanical refrigeration."[1]

Although household ice refrigerators were introduced in 1881 by the Leonard Refrigerator Company, no attempt was made to manufacture a mechanical refrigerating unit for the home for a great number of years. Kelvinator, sensing the public demand and need, brought out the first successful unit of this kind in 1914. This had to be a completely automatic refrigerating system, designed to run unsupervised

[1] "Ice and Refrigeration," November, 1924, p. 328.

by a competent operating engineer. Before a machine of this kind could be built, much research and development was necessary. New and adequate controls for maintaining required temperatures were needed, the old bulky machine had to be refined and made more compact; and the problem of noise which was of minor importance in industrial use became a major factor. Methods of manufacture had to be worked out which would give the highest degree of perfection of product and yet not be so costly that the price to the customer for the complete unit was exorbitant. Those and many other problems had to be solved before the domestic electric refrigerator became an actuality.

Through extensive and well-directed research, Kelvinator moved rapidly towards the solution. That its work was thorough is evidenced by the fact that today one may find many of the original units still in active service, after more than twenty years of duty. This vast background of experience both in laboratory and field has made Kelvinator one of the outstanding manufacturers of household refrigerating equipment. The Kelvinator Division of Nash-Kelvinator Corporation feels that it can point with pride to the history of its past.

As a consequence of this pioneering work we find the trouble-free mechanism of the present day. Improvements in construction, design, and efficiency are advanced every year. This constant effort to perfect electrical refrigeration has resulted in ever-greater savings for the individual owner, not only in the initial cost of the refrigerating unit, but even more in operating economy. A modern electrical refrigerator must be capable of maintaining adequate storage temperatures to check the deterioration of food by molds, yeast and bacteria, which lead to bad flavors, odors, and possible infectious diseases. To accomplish this, food must at all times be kept at temperatures below 50 degrees F., and here again Kelvinator pioneered with its built-in thermometer which clearly indicates to the housewife the exact operation of her refrigerator.

A reference in the Encyclopedia Brittanica to the refrigeration of foods provides a significant appraisal of domestic electric refrigeration in modern life, "It would be no exaggeration to say that no scientific advance since the advent of railways and steamboats has so greatly altered the economic life of Europe and America."[1]

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[1] Encyclopedia Brittanica, 14th Edition, Volume 9, p. 458.

Other Publications of

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Temperature Control Is Health Insurance—by Shirley W. Wynne, M.D., Dr. P.H., Formerly Health Commissioner of the City of New York.

An Economist's Appraisal of Domestic Electric Refrigeration—by Warren M. Persons, Ph.D., Consulting Economist.

Scientific Refrigeration in Relation to Nutrition and Health—by Lulu G. Graves, Consultant in Nutrition and Organization of Dietary Departments.

Lord Kelvin—Master of Heat and Cold.—An authoritative biography of the great British physicist, Father of Modern Electric Refrigeration and Air Conditioning.

Kitchen Temperatures—By Anne Pierce, Consultant in Home Economics. Includes plans for four "engineered" kitchens.

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